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Two Case Studies

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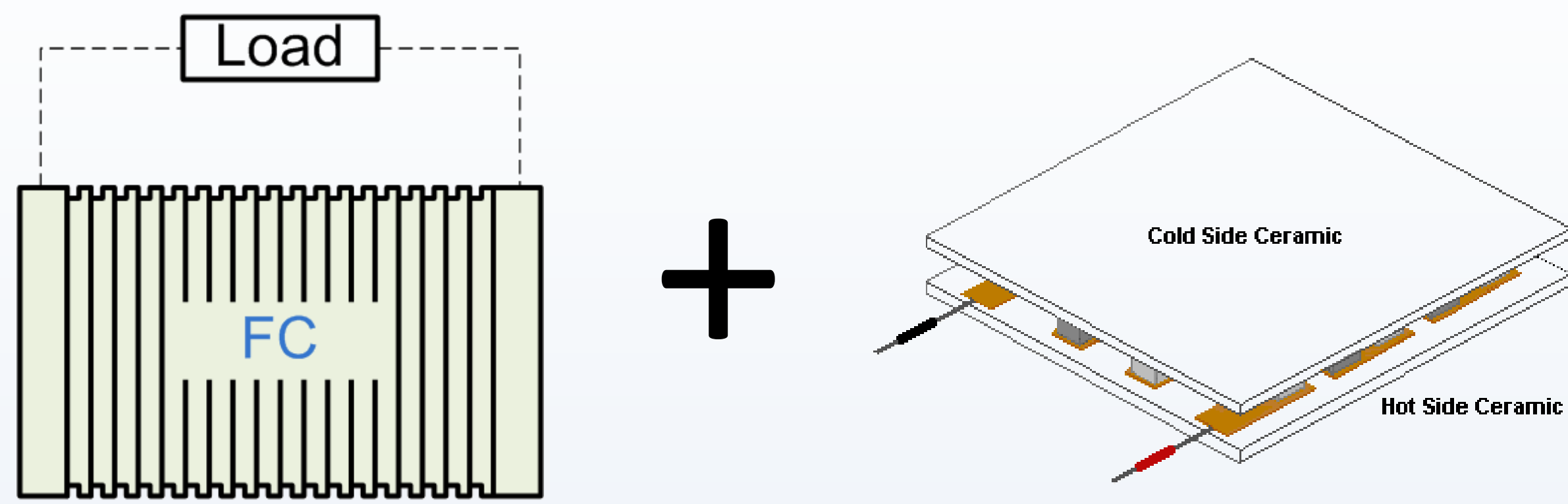
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Potential Usage of Thermoelectric Devices in a HTPEMFC System: Two Case Studies

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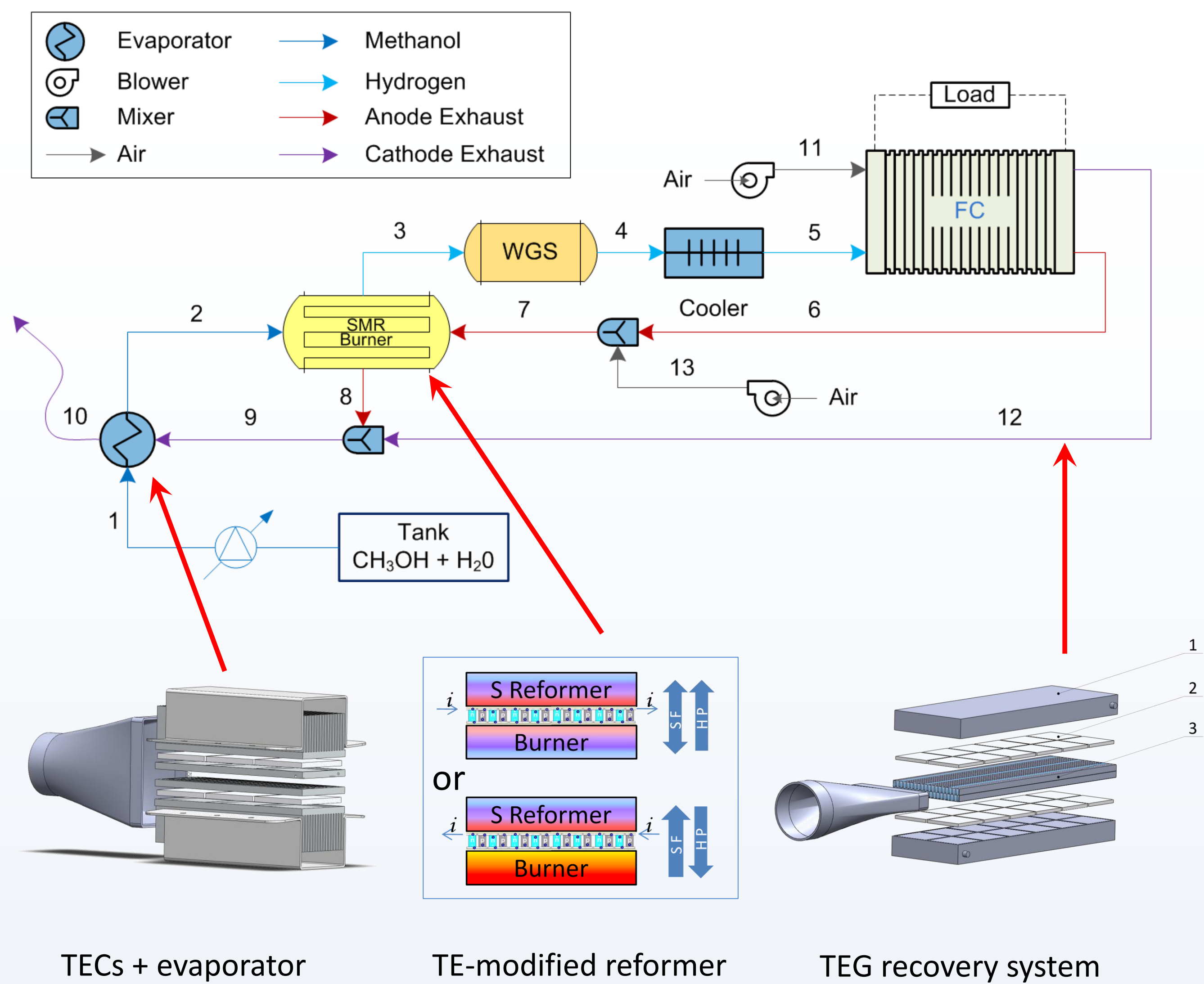
Introduction

Methanol fuelled high temperature polymer membrane fuel cell (HTPEMFC) power systems are promising as new generation vehicle engines, efficient and environmental-friendly. But a large amount of system waste heat is still exhausted unused. And by now, they still cannot get rid of large Li-ion batteries for system startup. System dynamic performance is also unsatisfactory. Because heat flux is uncontrollable during working condition fluctuating.



In this work, possibly useful waste heat from a HTPEMFC system under normal operating conditions and during system startup has been assessed separately for TEG heat recovery. To further optimize the TEG heat recovery system, a finite-difference model has been established and validated later in this paper. Finally, the use of TECs to improve system dynamics and reduce the heat loss in methanol evaporator is envisaged.

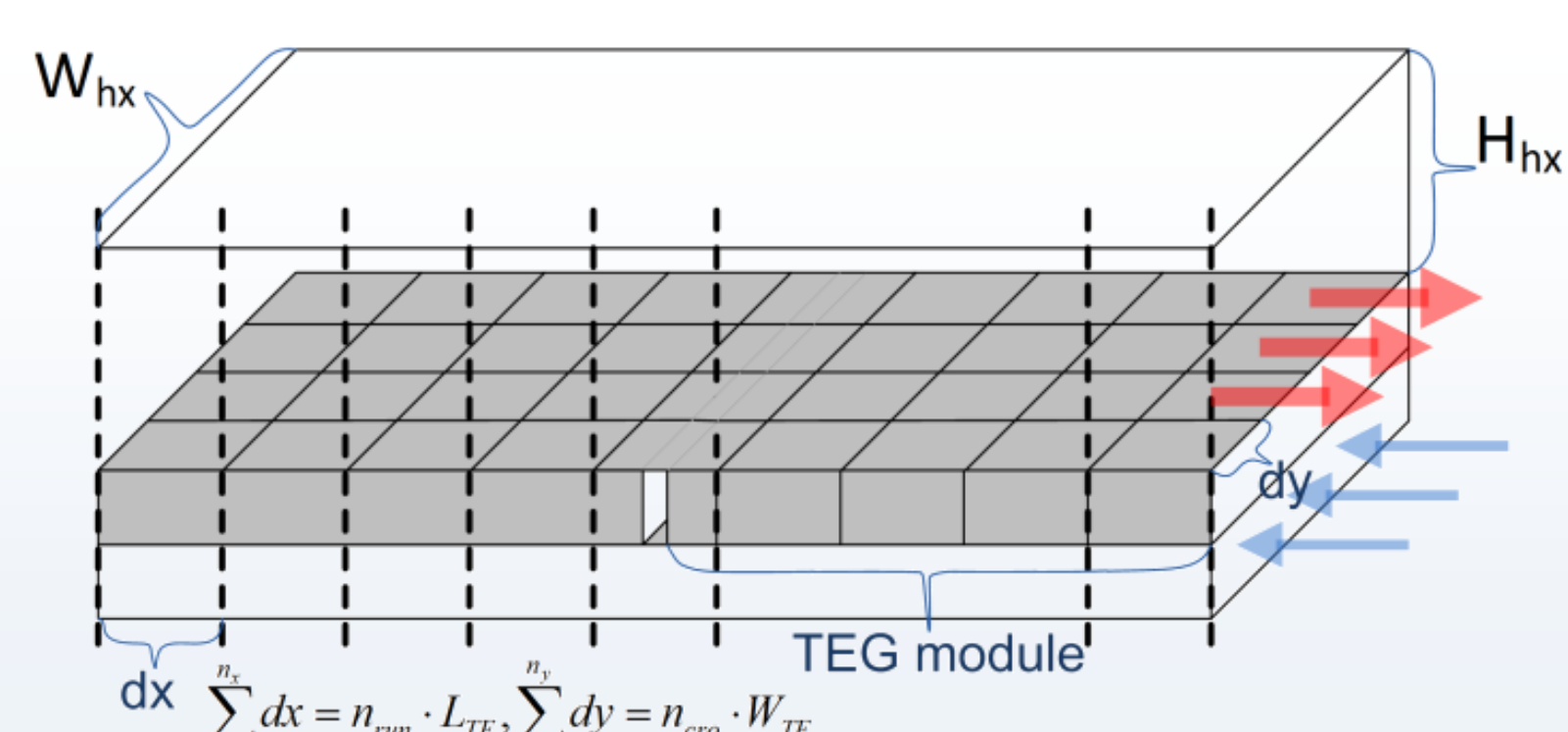
Objectives



- To improve the transient performance of methanol evaporator and SMR reformer with TECs.
- To reduce heat loss inside methanol evaporator during system startup.
- Using TEG heat recovery for electricity to improve system efficiency under normal working conditions and to reduce the system dependence on Li-ion battery during startup.

Methods

Finite-difference Model



To optimize the TEG heat recovery system, a finite-difference model has been built in engineering equation solver (EES) software. It is inspired by Espinosa's work and takes Smith's model for reference. Main equations are as follows.

- TEG properties

$$\sum_{i=1}^{n_{TE}} \sum_{j=1}^{n_{TE}} \alpha_i = \alpha_{TE}, \sum_{i=1}^{n_{TE}} \sum_{j=1}^{n_{TE}} R_{e,i} = R_{e,TE}, \sum_{i=1}^{n_{TE}} \sum_{j=1}^{n_{TE}} k_{i,j} = k_{TE}$$

- TEG power output

$$I_i = 0.5 \alpha_i (T_{h,TE}(i) - T_{c,TE}(i)) / R_{e,i}$$

$$w_{TE,max}(i) = \alpha_i I_i (T_{h,TE}(i) - T_{c,TE}(i)) - I_i^2 R_{e,i}, P_{TE,max} = \sum_{i=1}^{n_{TE}} w_{TE,max}(i)$$

- Heat transfer

$$m_h c_{h,i} (T_h(i) - T_h(i+1)) = UA_{h,HX} (T_h(i) - T_{h,TE}(i))$$

$$m_h c_{h,i} (T_h(i) - T_h(i+1)) = \varepsilon_{eff}(i) m_h c_{h,i} (T_h(i) - T_c(i))$$

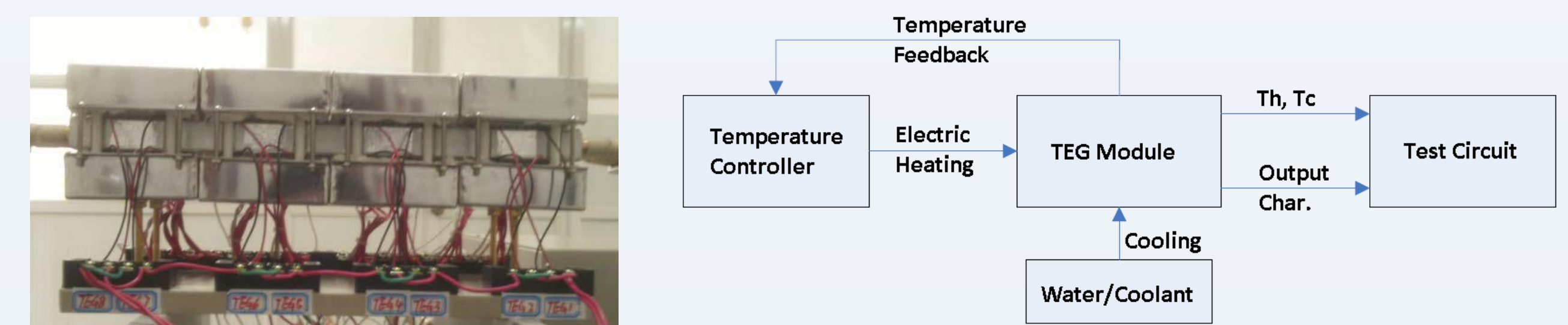
$$\varepsilon_{eff}(i) = 1 - \exp(-NTU(i)), NTU(i) = UA_{tot}(i) / (m_h c_{h,i})$$

$$1 / UA_{tot}(i) = 1 / UA_{h,HX}(i) + 1 / UA_{TE}(i)$$

- Pressure drop

$$\Delta p = (G^2 / (2 \rho_m)) [4 f \cdot L_{flow} \rho_m / (D_h \rho) + (1 + \sigma^2) ((\rho_m / \rho_{out}) - 1)]$$

Emulation Experiments

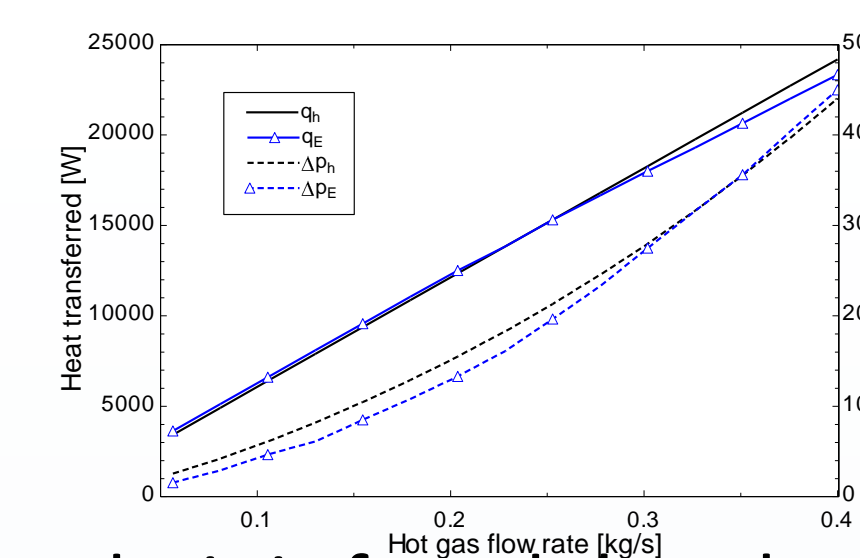


Recent Results

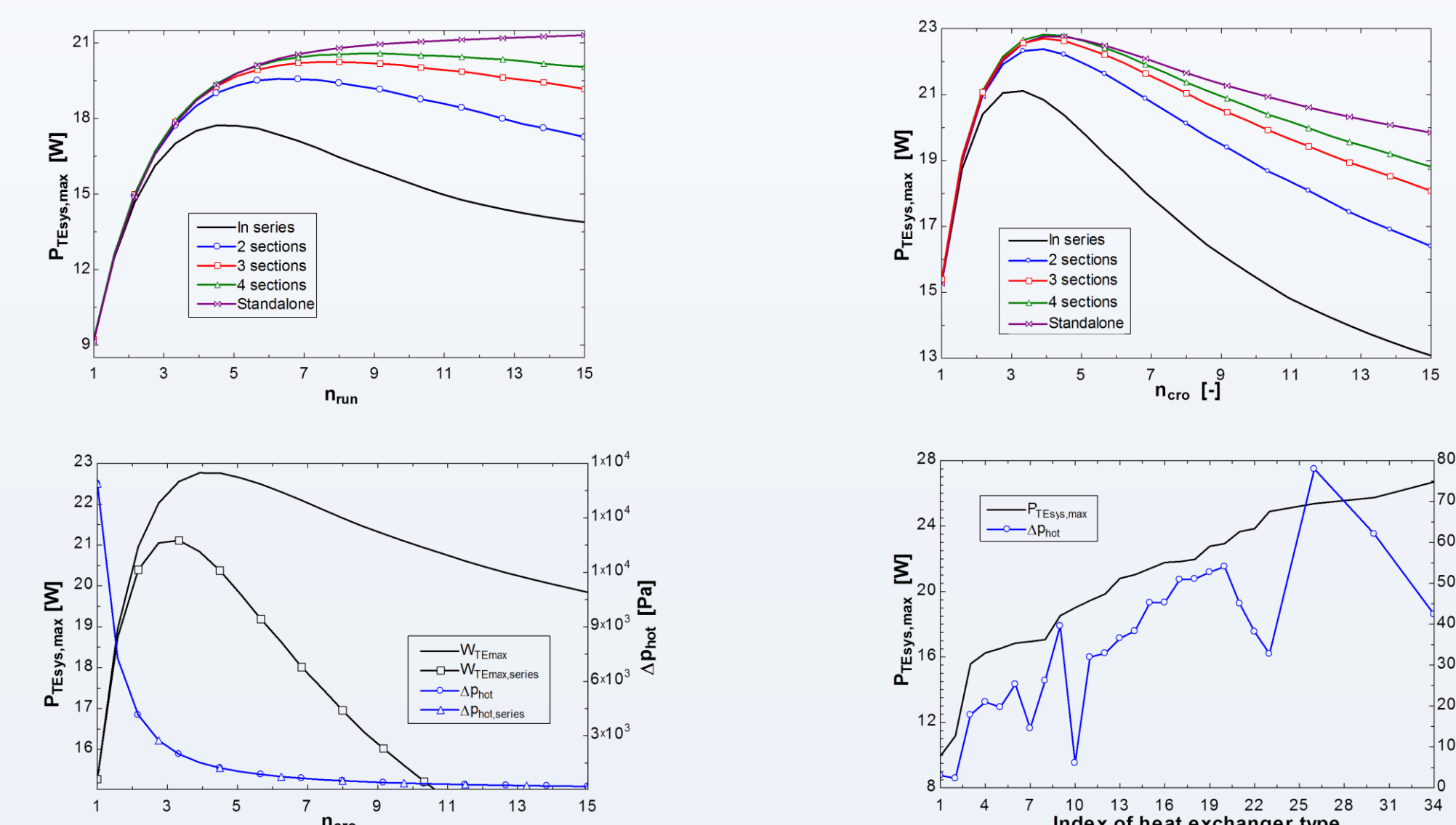
- Heat recovery potentials and model validation

Position	T_h (°C) / T_c (°C)	Heat flux (W)	TEG material	Max TEG power
Fuel cell - Evaporator	145/25	1012	Bi2Te3 & (Bi,Sb)2Te3	58W
Evaporator	250/70	329	Mg2SiSn & Zn4Sb3	24W
Reformer	400*/250	160	Mg2SiSn & Zn4Sb3	7W*
Cooler	205/25	39	Bi2Te3 & (Bi,Sb)2Te3	3.1W
Burner exhaust	137.5/25	34.5	Bi2Te3 & (Bi,Sb)2Te3	2W

*The temperature of hydrogen catalytic combustion is in the range from 100 °C to 2210 °C. Here a typical temperature is used.



- Sensitivity analysis: Through the sensitivity study, it is found that the hot fluid temperature contributes 73.98% of the system power output sensitivity. When temperature goes down, TEG power output decreases sharply and vice versa.
- Influences of TEG heat recovery system parameters



Conclusions

- TEGs and TECs are of great potentials in improving the HTPEMFC power system.
- Various parameters of the TEG system influence its maximum power output: TEG electric connection, size, exchanger type and configuration.

Acknowledgements

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